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TECHNICAL DISCUSSION

Efforts continue to be directed along two parallel and complimentary lines, one involving the numerical approach discussed in Ref. 1, and the other involving a perturbation solution to the fluid equations of motion for small values of the dimensionless boundary layer thickness (based on the panel length).

The numerical technique is being used to conduct parameter studies of the effects of flow Mach number, boundary layer thickness, panel length/width ratio, and panel mass ratio. Future efforts will consider pressurization and panel buckling.

The perturbation approach has been developed to a point where generalized aerodynamic forces due to arbitrary time histories of panel deflection are available for two-dimensional flow. That is, if a panel deflection of the form

$$w_p(t)\ \psi_m(x/a) \tag{1}$$

produces a pressure $p_m(x/a,\ t)$ on the panel, then the generalized forces

$$Q_{mn}(t) = \frac{1}{\rho U^2} \int_0^a p_m(x/a,\ t)\ \psi_n(x/a)\ \frac{dx}{a} \tag{2}$$

have been calculated as a power series in the dimensionless boundary layer thickness δ/a:

$$Q_{mn}(t) = Q_{mn}^{(0)}(t) + \frac{\delta}{a} Q_{mn}^{(1)}(t) + \cdots \tag{3}$$

wherein $Q_{mn}^{(0)}(t)$ is the classical potential flow result, and $\frac{\delta}{a} Q_{mn}^{(1)}(t)$ is a first order correction for the presence of the boundary layer. The extension to include three-dimensional effects is straightforward, and will be completed within the present contract period.

A comparison of the present results with those obtained by the numerical method of Ref. 1 for the case of sinusoidal panel motion at a reduced frequency $K \equiv \frac{\omega a}{U}$ of 0.5 is presented in Figs. 1 and 2. Both the in-phase (real) and out-of-phase (imaginary) components of Q_{11} and Q_{12} are shown. The two sets of results are comparable for small values of δ/a, but sizable differences appear at $\delta/a = 0.1$. The agreement can presumably be improved by including more terms in (3). On the other hand, boundary layers thinner than $\delta/a = 0.1$ can have a considerable effect on panel flutter, so that the results are of interest in their present form.

The present theory has also been compared with recently published measurements[2] of the pressure on wavy walls immersed in a boundary layer. In this case the comparison involves the pressure itself rather than the generalized forces:

$$\frac{p}{\rho U^2} \equiv p^* e^{i\alpha x}$$

$$p^* = p^*_o + \varepsilon\, p^*_1 + \varepsilon^2\, p^*_2 + \cdots$$

Here $\alpha \equiv \frac{2\pi}{L}$ is the wall wave number, so that ε is proportional to the boundary layer thickness divided by the wall wavelength:

$$\varepsilon = \alpha\delta = 2\pi \frac{\delta}{L}$$

The amplitude and phase angle of the pressure due to a unit wall wave height are shown in Figs. 3 and 4 for M = 1.1. The results are shown accurate to zero, first and second order in ε in both figures. A comparison of the second order with Fig. 15 of Ref. 2 is shown in Figs. 5 and 6. For these calculations a "1/7 power law" was assumed for the boundary layer profile. The same assumption was used to relate the geometric boundary thickness δ to the displacement thickness δ^* used in Ref. 2. The agreement is seen to be relatively good out to $\delta^*/L \doteq .02$, which corresponds in this case to $\delta/L \doteq .12$.

The present work will be extended to include three-dimensional flows. The generalized forces will then be used in representative flutter calculations, to further access their usefulness.

The principal investigator presented a seminar at Ames Research Center on July 28, 1971, discussing progress to that date.

REFERENCES

1. Dowell, E. H., "Generalized Aerodynamic Forces on a Flexible Plate Undergoing Transient Motion in a Shear Flow", AIAA Journal, Vol. 9, No. 5, pp. 834-841, May 1971.

2. Muhlstein, L. and Beranek, R. G., "Experimental Investigation of the Influence of the Turbulent Boundary Layer on the Pressure Distribution Over a Rigid Two-Dimensional Wavy Wall", NASA TN D-6477, August 1971.

BUDGETARY DISCUSSION

One graduate student and one research staff member are presently working on this program in addition to the principal investigator.

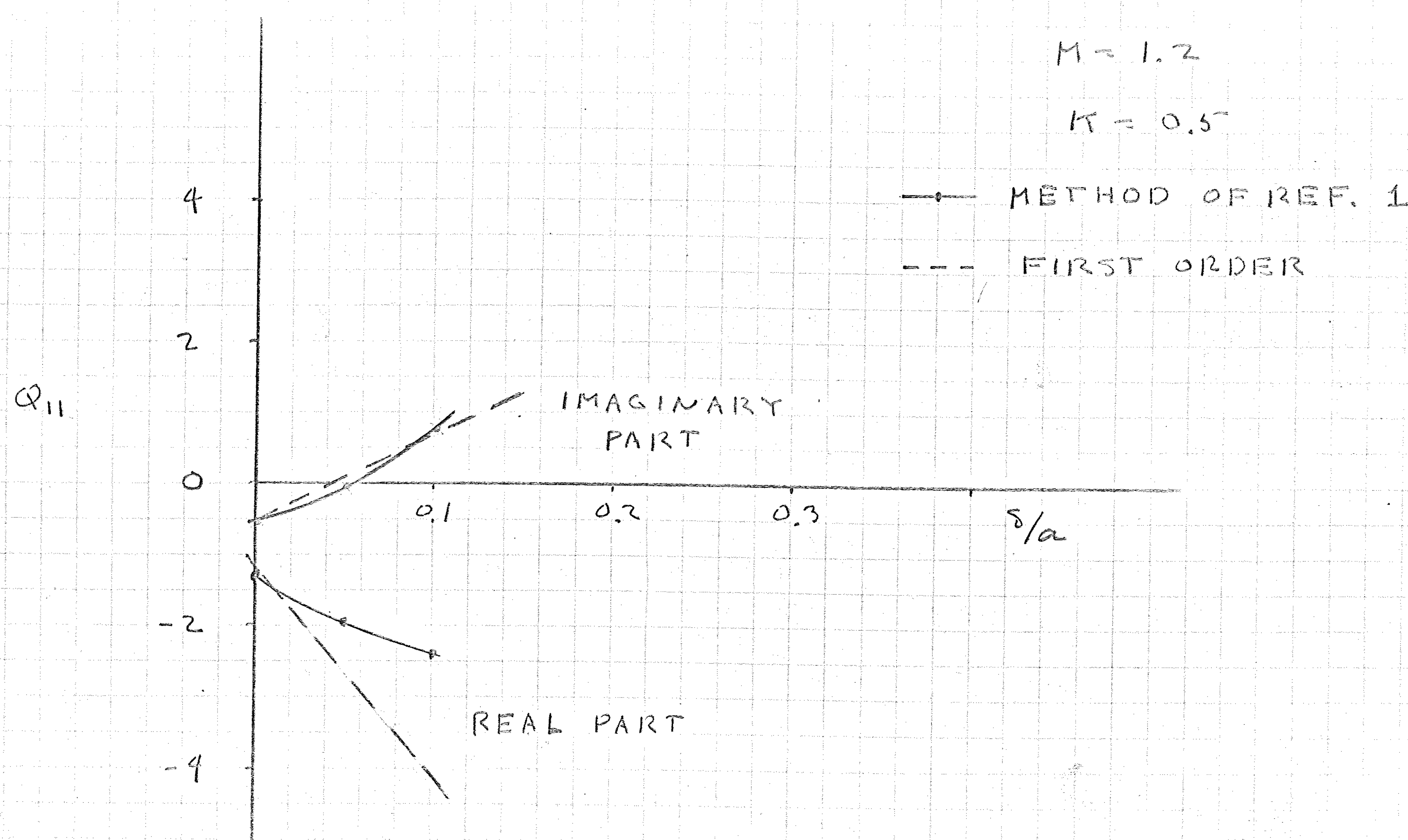

M = 1.2
K = 0.5
METHOD OF REF. 1
FIRST ORDER
Q11
4
2
0
-2
-4
IMAGINARY PART
REAL PART
0.1
0.2
0.3
δ/a

FIG. 1

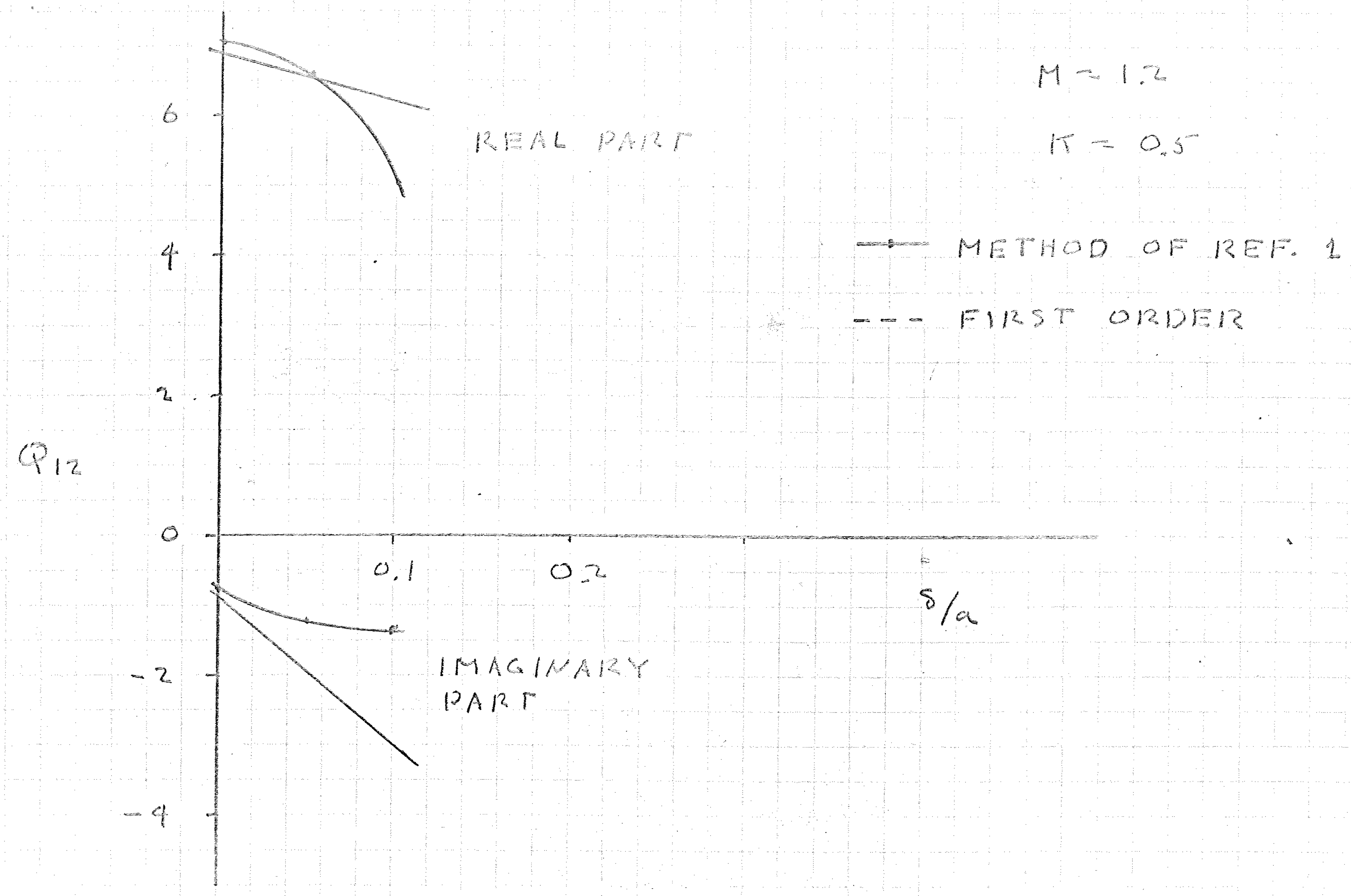

M = 1.2
K = 0.5
METHOD OF REF. 1
FIRST ORDER
REAL PART
IMAGINARY PART
Q_{12}
6
4
2
0
-2
-4
0.1
0.2
δ/a

FIG. 2

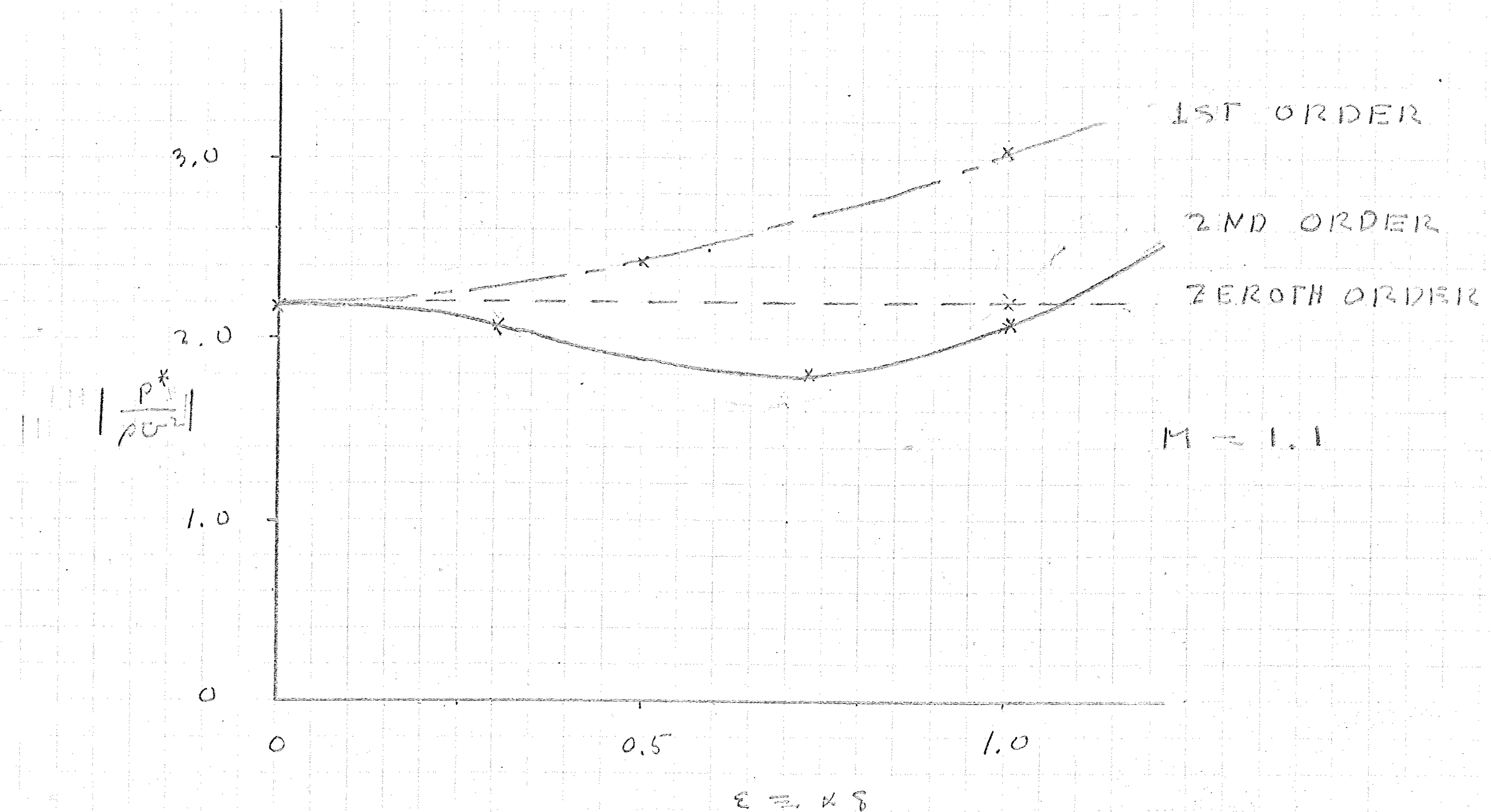
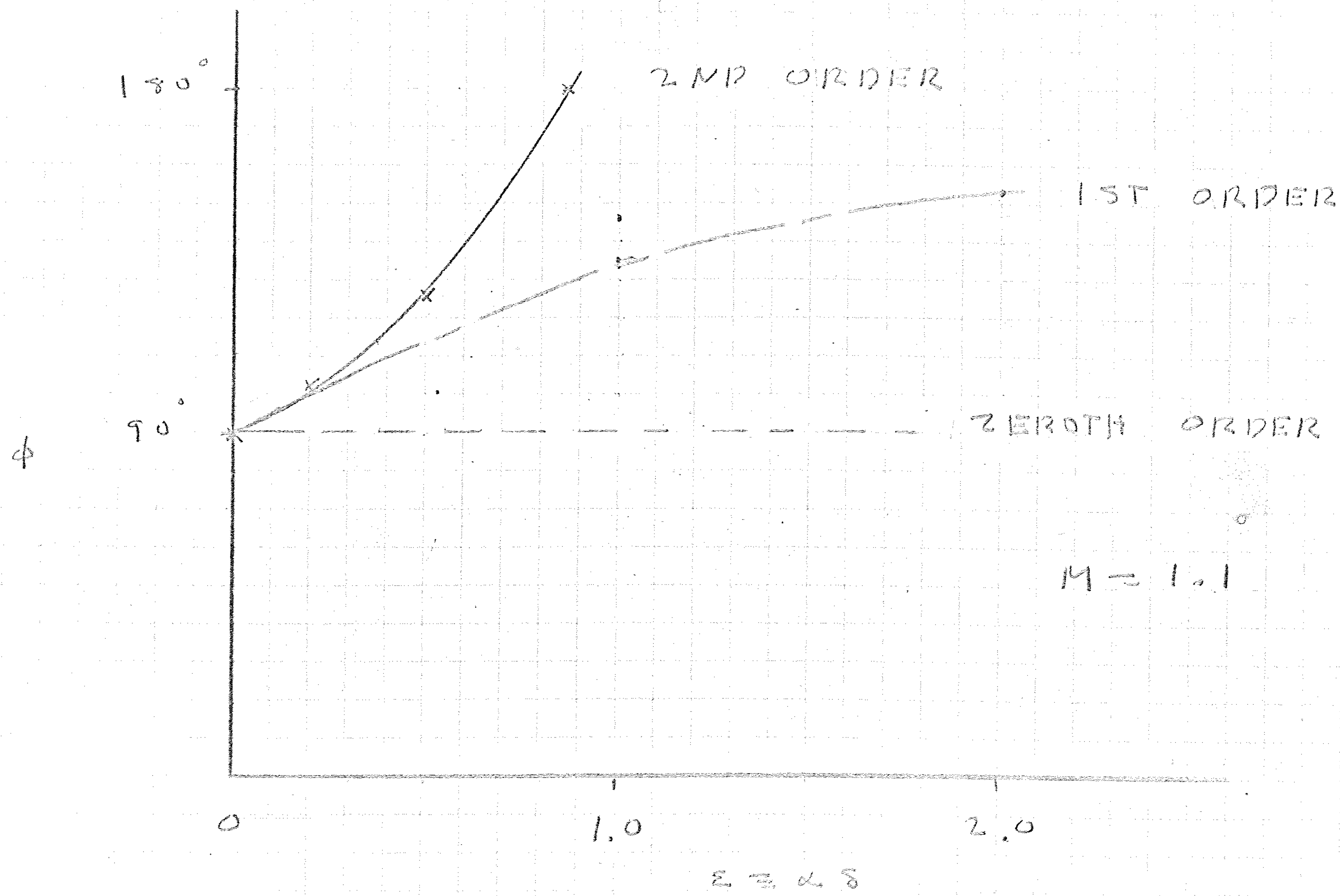

1ST ORDER
2ND ORDER
ZEROTH ORDER
M = 1.1
3.0
2.0
1.0
0
0.5
1.0
$\left|\frac{p^*}{\rho U^2}\right|$
$\varepsilon = \kappa\delta$

FIG. 3



180°
90°
ϕ
2ND ORDER
1ST ORDER
ZEROTH ORDER
$M = 1.1$
0
1.0
2.0
$\varepsilon = \alpha\delta$

FIG. 4

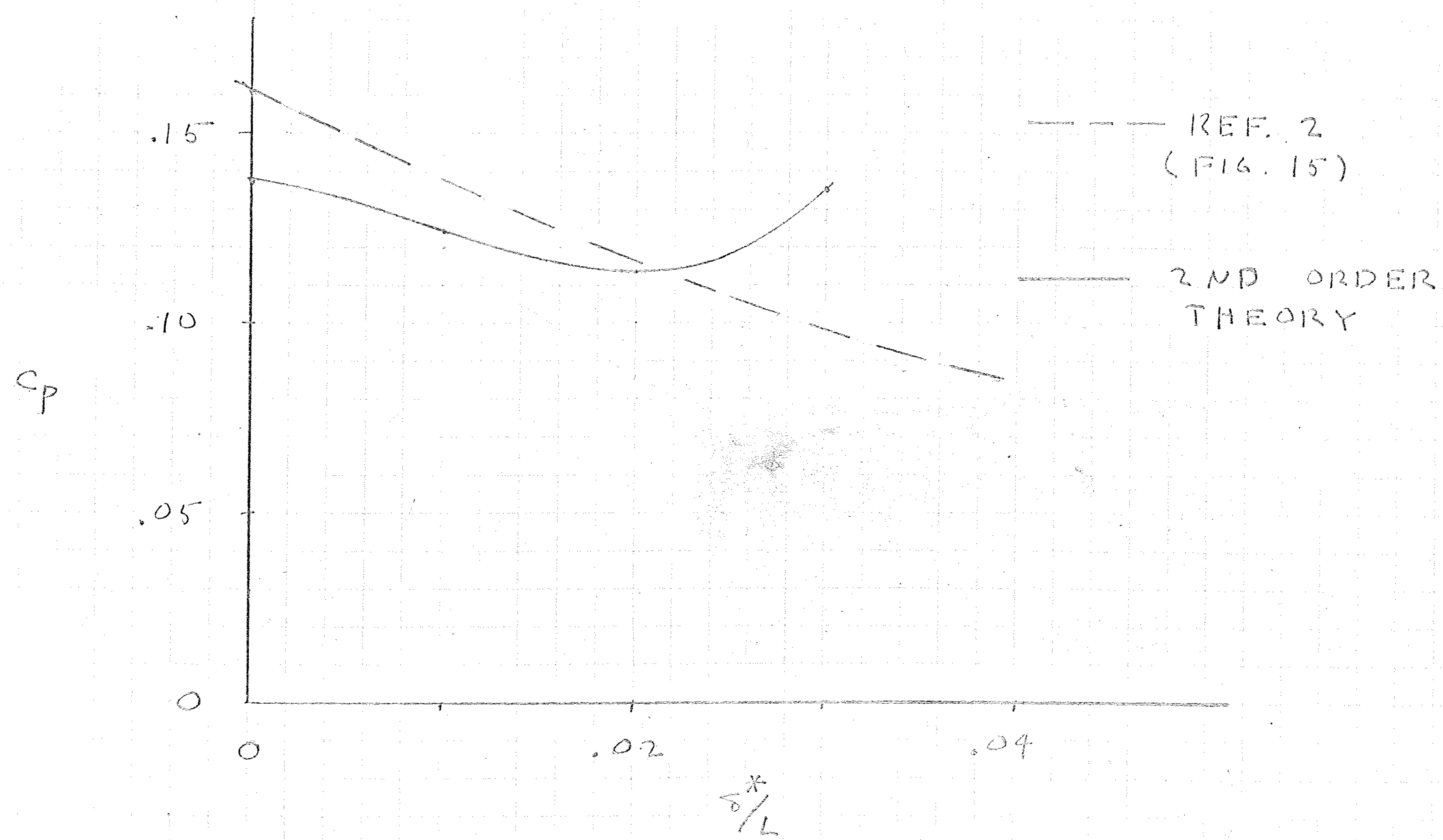


FIG. 5

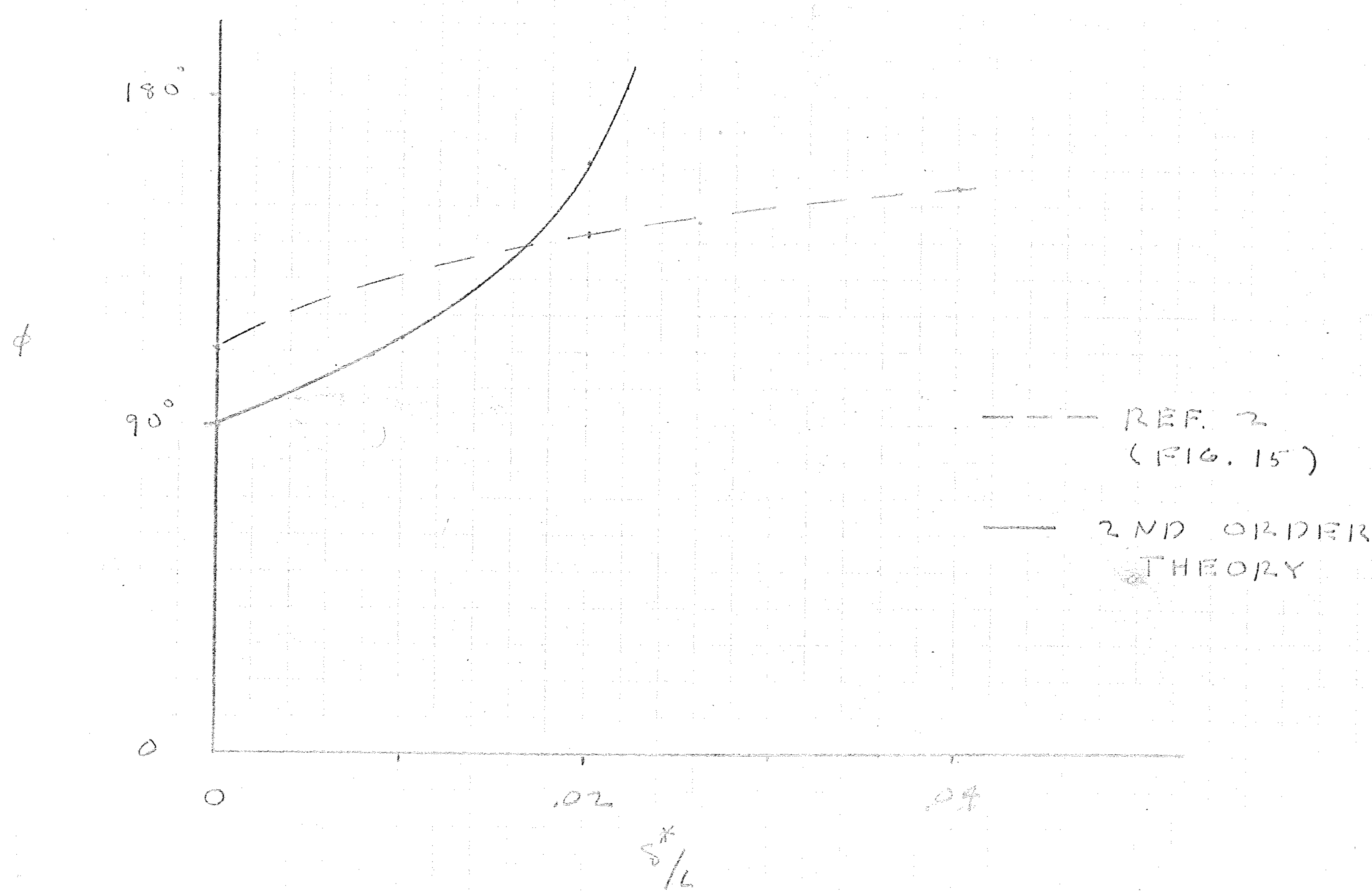


FIG. 6